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SOME PHYSICAL PHENOMENA INVOLVED IN THE  
MECHANICAL THEORY OF THE CORONA.

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By J. M. SCHAEFERLE.

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The manuscript of the Report of the Total Solar Eclipse of December 21-22, 1889, has been for some time in the State Printing office, but it is likely that the issue of the Report will be very much delayed, owing to the great amount of work in this office and to the necessity of keeping up with the printing for the State Legislature, now in session.

It, therefore, seems to be worth while to give here a short account of the principles and results of the mechanical theory of the corona as they are presented in the Report in question. A general outline of the theory is printed in the *Publications* A. S. P., vol. II, p. 68. (See also p. 260.) In the unpublished Eclipse Report the subject is treated in the following order:

In § 1, after some introductory remarks, the three fundamental observed facts, on which the whole theory is based, are stated, and certain conclusions drawn from these and other observed facts. Extracts from the works of solar physicists are also quoted.

The three fundamental theorems are:

- (1) The eruptions on the sun's surface are most active and numerous in the sun-spot zones.
- (2) The sun rotates about an axis passing through its center.
- (3) This axis is inclined to the plane of the earth's orbit at an angle of about  $82\frac{3}{4}^{\circ}$ .

In § 2, formulæ are derived which represent the motion of a single particle normally ejected from the surface of the sun from any point within the sun-spot zones (mean latitudes  $\pm 15^{\circ}$ ) and other equations which represent the shape of a stream of such particles ejected continuously. The results are tabulated, so as to exhibit the forms of such streams ejected with different initial velocities.

A consideration of these results shows that the observed shapes of the equatorial extensions or wings of the corona can be satisfactorily accounted for by supposing them to be the envelopes of systems of streamers ejected from the sun-spot zones with initial velocities of less than 380 miles per 1<sup>s</sup> (such velocities as have been observed in the higher regions of the prominences, for example.)

§ 3 treats especially of the general coronal form as seen in projection from the earth at different times of the year.

In § 4, the fundamental formulæ for the inclination of optical rays caused by the superposition of two or more parallel wire screens are deduced; and it is shown that the "polar rays" can be satisfactorily accounted for in this way.

That is, the "polar rays" which we see in any corona, have no objective existence, but are caused by the superpositions of nearly right line streams, one projected upon the other. These right line streams, of which there are a great number, have their bases within the sun-spot zones (some in front, some behind the sun), and in eclipses appear beyond the moon's circumference. They overlap and are seen in perspective projection on the sky, and produce subjective appearances of curved rays, somewhat as the patterns of watered silk are produced. A theory of this projection is given, and it is shown, both mathematically and experimentally, that the curious curvilinear forms of the "polar rays," which are actually observed, can be produced by the perspective overlapping of systems of nearly right line streamers originating within the sun-spot zones.

The same phenomenon takes place in the equatorial extensions or wings, but it is not so marked to the eye, for the reason that we are here looking through a greater depth of streamers, and because there are many more individual streamers concerned in the appearance. The comparison with observation must here be with the *envelope* or exterior boundaries of the wings in general.

§ 5 relates to the change in position of the coronal poles with reference to the poles of the sun, which is due to a change in the heliocentric latitude of the observer.

In § 6, the theoretical trumpet-shaped form of the outer corona is deduced.

In § 7, the subject of *rifts* in the corona is treated.

§ 8 gives the methods for the graphical representations of the "polar rays," with plates in illustration.

In § 9, the theory is compared with all available observations of previous eclipses—whether drawings or photographs. As is to be expected, the general agreement of the photographs with the theory is far more striking (and important) than that of the drawings, which are subject to personal errors, but, even in the case of the drawings, the agreement is most marked and more satisfactory than was anticipated.

§ 10 gives the principal conclusions reached, with the addition of some speculative remarks relating to the solar protuberances, auroras,

comets and variable stars. The conclusions may be summarized as below.

All the principal phenomena observed in past solar eclipses can be satisfactorily accounted for and even graphically reproduced according to well known mechanical principles.

Many of the observed details of the corona, which, if regarded as the projections of real forms in space, would be wholly contrary to known laws of motion, are, by this theory, not only demonstrated to be in accordance with rigorous laws, but even the most grotesque of these details can be experimentally reproduced without in any way changing or straining the fundamental facts on which the whole theory rests.

Very suggestive optical phenomena can be produced experimentally by the perspective overlapping of two or more sets of approximately straight and nearly parallel luminous lines, each set of lines making a small angle with the lines of the other sets. For certain positions the slightest shift in the observer's position produces very rapid changes in the positions of the curved rays (or concentric arches) formed. Beyond certain distances only these optical rays can be distinguished, the real luminous lines being lost in the rays.

As a direct outcome of the Mechanical Theory certain physical phenomena result, some of which are here indicated.

(I) All parts of a given unperturbed stream will be in a heliocentric latitude nearly equal to the latitude of the point of ejection.

(II) For a constant ejective force the periodic time  $t$  will be the same for all parts of the stream.

(III) The chance of collision of a returning with an outgoing stream varies inversely as the square of the distance of the point of collision, from the sun.

(IV) Near the sun, therefore, collisions must occur which tend to retard or stop the outgoing streams, resulting in a temporary increase in the heat of the combined colliding masses (causing a consequent increase in the brightness of the corona at such places, and at the same time rendering the coronal detail more confused.) This heat will tend to be largely dissipated before such masses fall back into the sun, which they will then reach with comparatively small velocity and low temperature. Unretarded returning streams on striking the sun will tend to greatly raise the temperature at the points of impact; perturbed returning streams could, of course, strike all parts of the sun's surface. Unperturbed returning streams will always fall within the limits of the sun-spot zones.

(V) So long as the incoming streams are very numerous the outgoing ones will, in a great measure, be stopped, so that, after the interval  $t$ , there will be comparatively few returning streams; a direct result of this state of things is to allow free passage for the outgoing streams, which, since there are now but few collisions, results in (1) an apparent diminution in the brightness of the corona, (2) more regular and sharply defined detail, and (3) in general a more uniformly illuminated solar surface might be expected, when there are but few or no returning streams. (The periodic character of this intermittent motion can be well illustrated by means of a fine vertical jet of water. The vertical vibratory motion of a light ball, often to be seen in water fountains, is also a good illustration.)

(VI) If the ejective force is such as to make  $t$  about five years, a complete cycle of changes will take place in the time  $2t$ , and after the same manner as is observed in the sun-spot cycle. It is rather remarkable that the aphelion distance of the streams corresponding to this value of  $t$  is nearly the same as *Jupiter's* distance from the sun; so that the perturbations produced by this planet may have more to do with the regularity of the period than the assumed constant force of ejection. The initial velocity required to just carry a particle from the sun to *Jupiter* is but little less than a parabolic velocity. For an initial parabolic velocity *Saturn*, alone considered, would, on the same hypothesis, cause a complete cycle of less marked changes in twenty years, *Uranus* in sixty years, and *Neptune* in one hundred and twenty years. The comparatively insignificant planets inside of the orbit of *Jupiter* would cause minor variations, corresponding to cycles, which, even for *Mars*, would be of less than two years duration.

(VII) The chance of the earth passing through one of these outgoing streams, which have a mean latitude of  $15^\circ$  is less than it is for an incoming perturbed stream.

(VIII) A phenomenon similar to the observed zodiacal light would result from the projection of many such streams in space, and the observed extent of this light proves that the matter which causes this illumination extends to greater distances from the sun than the earth's distance.

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PREDICTIONS RELATING TO THE ANNULAR ECLIPSE OF THE SUN,  
JUNE 6, 1891.

The following data, additional to those already given on page 67, may be useful. *Position angle of the points of first and last contact* (counted from N. through E.)

For Mt. Hamilton; *first*  $288^{\circ} 19'$ ; *last*  $28^{\circ} 56'$ ,

For San Francisco; *first*  $287^{\circ} 18'$ ; *last*  $30^{\circ} 16'$ .

J. M. S.

UNITED STATES NAVAL OBSERVATORY.

From the Report of the Superintendent (Captain F. V. McNAIR, U. S. Navy) for 1890 the following paragraph is extracted :

“ PERSONNEL.

“Out of the corps of twelve professors of mathematics in the Navy, there are now only six who are on duty as astronomers; one of the ablest of these will be retired shortly, leaving but five for service at the Observatory and Nautical Almanac Office. \* \* \* The issuing of the annual volumes of the observatory has been for years falling farther and farther behind, until now publication is five years behind the observations, and the amount of work done has been growing less and less. Important improvements in instruments and in methods of observation, as well as new and equally important lines of research, many of which are actively pushed forward at the principal Government observatories, have here been entirely neglected on account of the lack of practical astronomers to make independent observations and to carry on special investigations in conjunction with other observatories. \* \* \*

“From the organization of this naval institution, its personnel must be drawn principally from officers of the Navy; and it is necessary to appoint some professors of mathematics, astronomers of known experience, as it is mainly to this corps that the observatory has to look for aid to keep up its astronomical reputation.

“It is scarcely necessary to add that, when the new Naval Observatory is completed and equipped, the force of astronomers and assistant astronomers will have to be materially increased if the observatory is to be worthy of our great and progressive country.”

The Government Observatory ought to be the chief astronomical establishment of the country and equal to any similar institution in the world. For some years past it has been falling behind its true rank, as is pointed out by the Superintendent. A fine observatory building is nearly completed and, in a short time, the instruments will be transferred to their new home. For every reason it is desirable that some change of policy should mark the beginning of the new epoch, and that the observatory should take its legitimate place at the head of astronomical science in America. There is no reason